

Quantum Basis of Lorentz Symmetry

Paul Korbel
Institute of Physics,
University of Technology, ul. Podchorazych 1,
30-084 Cracow, Poland

February 1, 2008

Abstract

An unconventional outlook on relationship between the quantum mechanics and special relativity is proposed. We show that the two fundamental postulates of quantum mechanics of Planck and de Broglie combined with the *idea of comparison scale* (explained in the paper), are enough to introduce relativistic description. We argue that Lorentz group is the symmetry group of quantum, *preferred frame* description. We indicate that the departure from the orthodox relativity postulate allows us, in easy way, to make special relativity and quantum mechanics indivisible whole.

1 Introduction

The principle of equivalence of inertial frames basing on the Galilean transformation provides the foundations of classical, i.e. Newtonian physics. The classical physics is complete, it agrees well with our intuition and treats the time as the absolute quantity. This makes that classical approach turns out to be the natural and well-understood. However, the research on electricity and magnetism, which finally led Maxwell in 1864 to his know equations, and next the observations of Michelson and Morley in 1887, which excluded the possibility of ether existence, have revealed some new physical phenomena, the interpretation of which was very difficult in spirit of Newtonian physics. Note, that derivation of Maxwell equations was possible not only because of the knowledge of the properties of the electric and magnetic fields and mutual correlations between them, but also due to the assertion that the light always propagates at a *finite* speed c . However, the most surprising observation, approved just by Michelson and Morley, was that the speed of light does not depend on the state of motion of the emitting body. This observation has limited the range of acceptability of the theories invariant with respect to the Galilean transformation. Consequently, the natural need was to build up a new dynamical theory for which the observation of Michelson and Morley would be intrinsically incorporated. Such theory was formulated by Einstein in 1905, who imposed the physical meaning on the Lorentz transformation. According to his interpretation the time is no longer absolute quantity, so that “we cannot attach any *absolute* signification to the concept of simultaneity...” [1].

At the beginning of last century, i.e. at the time when the quantum mechanics had come into being, there appeared a new sort of physical observations needing a departure from the classical treatment too. It is known that early attempts of construction of wave equation for material particle in much degree were inspired of mathematical structure of Maxwell equations. This led Schrödinger and others [2] to discover the relativistic scalar wave equation, usually called the Klein-Gordon equation. However, it turned out that this relativistic equation provided the values for the spectrum of hydrogen atom that were not fully correct compared to the experimental data. The source of this discrepancy, as noticed by Schrödinger, was the lack of electron spin in calculations being done [3]. Schrödinger improved then his results by substituting the relativistic equation for its non-relativistic approximation (known just as the Schrödinger equation). This allowed him to introduce “by hand” the spin degrees of freedom and correct the earlier results.

Nevertheless, within the framework of non-relativistic approach there is no self-consistent way to introduce spin degrees of freedom into wave equations. On the other hand, only non-relativistic approach allows us to treat the time as an absolute quantity. In consequence one finds a sharp distinction between the quantum mechanics and relativistic quantum field theory. Thus, the prevailing conviction is that special relativity and quantum mechanics are the separate realms that cannot be combined in a simple manner, if possible at all.

At the recent stage of development in physics, i.e. after hundred years later

the quantum mechanics and special relativity were discovered, it is hard to expect that any further progress of currently discussed issues will solve the problem of separation of relativity from quantum mechanics. Therefore, perhaps the most plausible way to overcome this difficulty is a flashback overview upon the old ideas rather than the pursuit of new ones. In particular it is worthwhile to reexamine the postulate of relativity of motion in the context of quantum measurement, as well as, the meaning of time in the light of fundamental postulates of quantum mechanics.

The purpose of this paper is to show that similarly like the Galilean group constitutes the foundations of classical physics, the Lorentz group constitutes the foundations of quantum mechanics. In other words, we prove that special relativity is integral part of quantum mechanics. In particular, it is shown that the description based on Lorentz symmetry does not exclude the absolute time meaning. Nevertheless, a thorough refinement of interpretative foundations of special relativity is needed. This work tackles these issues in the most elementary way. The structure of the paper is the following:

In **Section 2**, we put and reexamine the Einstein relativity postulate in the light of realistic quantum experiment. It is argued that each quantum observation is the *preferred frame* observation, where the role of the preferred frame plays the rest frame of observer.

In **Section 3**, we indicate that it is important to distinguish two time meanings. The first, classical meaning concerns the time as the measure of pace of observed changes. The other, quantum meaning, concerns the time as the energy measure in sense of inverse time units. We show that the Schrödinger quantum mechanics does not differentiate between the both time meanings, however, the relativistic quantum mechanics does. Furthermore, we also indicate that the source of Lorentz symmetry resides in freedom of choice of *comparison scale*, i.e. at the *scale* which is imposed on two physical quantities given in different physical units, like the energy and momentum or the distance and time. The symmetry that corresponds to this freedom of choice is called the *scaling symmetry* and it is described by *transformation of scaling*.

Presented in **Section 4**, $1 + 1$ dimensional (gauge) analysis concerns both: the space-time and momentum space description. The concept of *photonic frame*, where the *scaling transformation* has diagonal form, is introduced. We end up this section with an open question about photon states description in *photonic frame*.

In **Section 5**, we consider a *photonic frame* and another one, which is rotated around the origin of initial *photonic frame* about 45° . This new frame turns out to be the Minkowski frame and thus provides the proper (i.e. unambiguous) description of photon states. Additionally, one finds that *scaling transformation of photonic frame* corresponds to the Lorentz transformation of Minkowski frame.

In **Section 6** we still continue our $1 + 1$ dimensional (gauge) analysis to show that state vector of relativistic particle with mass can be composed of two massless (i.e. photon) state vectors. This reveals a composite structure of massive state and points out to its space-time extensions.

Finally, in **Section 7**, we generalize our discussion onto entire $3 + 1$ dimensional space-time. The quantum basis of space-time concept is disclosed. Indeed, it is shown that the *idea of scaling* constitutes the core of Lorentz group symmetry. Next, we discuss the issue of kinematical meaning of Lorentz formulas and provide plausible quantum-mechanical explanation of, so-called, time dilatation effect.

2 Preferred frame in classical and quantum approach

The first relativity principle says [1] “the laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of coordinates in uniform translatory motion”. This principle, first of all, expresses our faith in universal character of nature laws. However, our classical perception has led also to the classical conclusion that there is a transformation group that converts measurements made by one inertial observer to measurements made by another. Note, that this “principle-conclusion” applied to quantum world observations cannot be directly verified by any experimental technique and become the main source of difficulties with relativity interpretation.

To explain this, let us consider first the case of single observer and ask: is it possible for him to measure the speed of light or any other physical quantity outside his own rest frame? According to Bell [4] “the only ‘observer’ which is essential in orthodox practical quantum theory is the inanimate apparatus which amplifies microscopic events to macroscopic consequences”. However, each ‘observer’ may observe only in ‘his’ own rest frame and no other possibility exists. The conclusion is that observer rest frame, or in other words, the laboratory frame, always is the *preferred frame* where the nature laws can be discovered and described.

Next, let us consider the case of two observers being in relative motion and assume that they measure the same physical quantity. To verify in physical way the first relativity postulate, the observers, beside the measuring quantity, have also to measure their mutual space-time positions. But this in turn means that the observers have to be coupled. Since the above “principle-conclusion” refers only to independent observers it cannot be directly verified on experimental way.

Of course, the same physical phenomena may be observed by independent observers placed at different inertial frames, and we know that their theoretical predictions resulting from the same equations (although established for different boundary conditions) agree. However, this is just the case when the *relativity of inertial frames* manifests itself by the fact that *all (inertial) observers that make measurements in the same conditions obtain the same experimental results*. In consequence, the world seen by each of them looks the same. In other words, the relativity principle reflects the most basic property of physical observation,

namely, its ability to reproduction.

Without doubt Einstein relativity postulate is a result of replacement of the Galilean group with the Lorentz one in the Newton world. Just such approach is a real source of pile up difficulties encountered with any attempt of unification of special relativity and quantum mechanics. Simple arguments given in the paper indicates that origin of Lorentz symmetry is rather quantum then classical. Note, that quantum measurement, in contrary to the classical one, cannot avoid a meaningful influence of measuring apparatus on the final results. On the other hand, such influence must accompany each *preferred frame* observation and thus must be *preferred frame* dependent. So, if Lorentz symmetry reflects indeed a feature of description of the quantum world (what is going to shown clearly), it must concern also the *preferred frame* description.

3 Two meanings of time and photon dispersion relation

One may say that pure classical approach defines the time as the measure of pace of observed changes. We will say that such time definition determines the *vital-time* meaning. The time evolution of system should then follow a *vital-time* description. However, the quantum mechanics indicates also another time meaning. Namely, due to the postulate of Planck, generalized later by Einstein, the time may be used as the energy measure by means of inverse time units. According to Planck postulate, if quantum state is characterized by the wave of period T , its energy

$$\mathcal{E} = \frac{h}{T}, \quad (1)$$

where h is the Planck constant. Note, that eq. (1) itself does not provide any kinematical meaning of interval T , unless this time interval refers to physical process which kinematics is well established. Nevertheless, the very equation (1) set up the clear relationship between the energy and time interval which devoid of kinematical meaning will be called further the *frozen-time* interval. Thus, the *frozen* meaning of time simply means the energy measure in sense of eq. (1).

It is commonly thought, of course, that there is no distinction between the *frozen* and *vital* time meanings. Indeed, in Schrödinger approach there is no separation between both time meanings but the reason for that is quite simple. The Schrödinger quantum mechanics involves the classical dispersion relation

$$\mathcal{E} = \frac{p^2}{2m} = \frac{1}{2}mw^2, \quad (2)$$

where the energy of particle with mass m is expressed by means of particle momentum p , or particle velocity w , where the latter is just the parameter of kinematical description. Thus, the equivalence of energy formulas (1) and (2) makes that there is no ambiguity in understanding of time meaning. The *frozen* and *vital* meaning of time now, is the same.

Many textbooks start with dispersion relation (2) to construct next the Schrödinger equation. Such approach, in fact, marks out the way which Newtonian physics becomes the quantum mechanics. However, if there exists a more fundamental way to introduce quantum description, one would expect that, in particular, such approach itself should provide the form of dispersion relation for free particle. The aim of this section is to indicate the basis of such approach. First, we discuss the idea of energy-momentum *comparison scale* and derive the photon dispersion relation. This will allow us to show later that postulates of Planck and de Broglie combined with the idea of *comparison scale* are enough to derive dispersion relation for relativistic particle with mass. Presented approach, however, makes a clear distinction between the *vital* and *frozen* time meanings.

3.1 Energy-momentum comparison scale

The postulate of Planck relates particle energy \mathcal{E} to the wave period T . In similar way the postulate of de Broglie relates the particle momentum Π to the wavelength λ , where

$$\Pi = \frac{h}{\lambda}. \quad (3)$$

Thus, in simply quantum-mechanical manner these two postulates express a basic feature of quantum physics known as particle-wave duality. However, the issue that has been not realized so far is that these two postulates also provide a framework for relativistic description. To disclose this connection, first we introduce a concept of *comparison scale*.

Let us consider the most simple dispersion relation where particle energy \mathcal{E} and momentum Π are assumed to be proportional quantities, i.e. when

$$\mathcal{E} \sim \Pi. \quad (4)$$

Due to the postulates of Planck and de Broglie the same can be expressed with the aid of reciprocal quantities, i.e. the wave period T and wavelength λ , namely

$$T \sim \lambda. \quad (5)$$

However, the momentum and energy, similarly like the distance and time, are the two quantities given in different physical units. Thus, to compare them in direct way (and thus to replace above proportions with corresponding to them equalities) one needs to introduce a dimensional factor of velocity v , and thus to set the *comparison scale* for the momentum and energy and/or the distance and time.

Without losing generality, as well as, to simplify the discussion, now it is enough to limit the considerations to two dimensional (i.e. $1+1$) space. Let us then consider a linear dispersion relation in the form

$$\frac{\mathcal{E}}{v} = \sigma \Pi_1, \quad (6)$$

where Π_1 is the value of particle momentum in given frame, and $\sigma = \pm 1$. Since the value of Π_1 may be either positive or negative the introduction of σ allows us to avoid negative energy values. Nevertheless, a new possible way of quantum-mechanical interpretation of negative energy states will be discussed separately elsewhere.

In terms of reciprocal quantities eq. (6) takes the form

$$vT = \sigma\lambda_1. \quad (7)$$

The velocity v , which fixes the *comparison scale*, is settled, but, in fact, is a free parameter. Thus, the feature of the way which equations (6) and (7) were introduced, is the *freedom of choice of comparison scale* v , or in the other words, the *freedom of scaling*. On the other hand, as long as the velocity v does not refer to particle kinematics eqs. (6) and (7) have no kinematical meaning too.

To impose kinematical meaning on dispersion relation (6) or (7), let us assume that the system we describe consists of particles that always propagate at a constant velocity c , no matter how big their energies (or momenta) are. In a context of quantum field theory, actually, it is even better to say that we assume the existence of physical system which quasiparticle excitations (in a given medium) always propagate at the same velocity c . Note, that such idealized system, if only exist, might serve as the reference one to provide a general way of energy *mapping*

$$\mathcal{E} \rightarrow \frac{\mathcal{E}}{c} \equiv \Pi_0, \quad (8)$$

equivalent to the reciprocal time mapping

$$T \rightarrow \Delta\chi_0 \equiv cT. \quad (9)$$

Of course (and fortunately), such idealized system exists and is well-known, so it will be called simply the *photon system*. Thus for $v = c$, eqs. (6) and (7) respectively take the form

$$\Pi_0 = \sigma\Pi_1, \quad (10)$$

and

$$\Delta\chi_0 = \sigma\Delta\chi_1, \quad (11)$$

where λ_1 in (7) was substituted for $\Delta\chi_1$ for further convenience. Since the algebraic structure of *photon* fields is of no importance now, we shall call the “*photon* fields” all for which the dispersion relation (10) holds. Note, that eqs. (10) and (11) fulfill also more general conditions

$$(\Pi_0)^2 - (\Pi_1)^2 = 0 \quad \text{and} \quad (\Delta\chi_0)^2 - (\Delta\chi_1)^2 = 0. \quad (12)$$

3.2 The freedom of choice of comparison scale

The condition $v = c$, which has imposed the kinematical (*vital*) meaning on time, also has fixed the *comparison scale*. So, does it mean that initial *freedom of scaling* has been lost? In the case of practical calculations, i.e. when the

condition $v = c$ is used to evaluate the physical quantities, the answer is yes! However, the answer is no if one uses only the notation which does not refer to any special value of v . This is just the covariant notation. The arguments given in the paper are enough to show that the source of covariant description is the *freedom of choice of comparison scale*.

Indeed, let us express the velocity v by means of the preferred velocity c and some real scaling factor η as

$$v = c\eta^2. \quad (13)$$

If one substitute velocity v for $c\eta^2$ in (6), equations (10) and (11) transform into the new ones

$$\Pi'_0 = \sigma\Pi'_1 \quad \text{and} \quad \Delta\chi'_0 = \sigma\Delta\chi'_1, \quad (14)$$

where $\Pi'_0 = \frac{1}{\eta}\Pi_0$ and $\Pi'_1 = \eta\Pi_1$, and thus $\Delta\chi'_0 = \eta\Delta\chi_0$ and $\Delta\chi'_1 = \frac{1}{\eta}\Delta\chi_1$. It must occur as well

$$(\Pi'_0)^2 - (\Pi'_1)^2 = 0 \quad \text{and} \quad (\Delta\chi'_0)^2 - (\Delta\chi'_1)^2 = 0. \quad (15)$$

So, the freedom of choice of comparison scale v might be alternatively expressed through the preferred velocity c and scaling factor η .

4 Scaling transformation of *photonic frame*

In this section we address a problem of symmetry induced by the *freedom of choice of comparison scale*. Since the energy and momentum are, in general, the two independent parameters, dynamical properties of particle may describe a point in momentum space. Let us then consider a frame in momentum space, which energy and momentum axes, π_0 and π_1 , are assumed to be orthogonal. We will call this frame the (momentum) *photonic frame*. Due to eqs. (1) and (3) the dynamical features of particle can be expressed also in terms of reciprocal space description. In this case we use the (position) *photonic frame*, which orthogonal axes χ_0 and χ_1 provide us the coordinates of *frozen time* and *distance* intervals. We assume, of course, that energy (time) axis is given in momentum (length) units, which means that our frame has built-in *comparison scale* η .

Let us call the frame for which $\eta = 1$, the *preferred frame*. In this frame the photon dispersion relation has the form (10) or (11). Therefore, the *rescaled* dispersion relations (14), are to be seen as the *photon* dispersion relations given in frame other than preferred ($\eta \neq 1$). The transformations that relate appropriate *photonic frames* determined for different *comparison scales*, then must take respectively the following forms: in momentum space

$$\begin{pmatrix} \pi'_0 \\ \pi'_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\eta} & 0 \\ 0 & \eta \end{pmatrix} \begin{pmatrix} \pi_0 \\ \pi_1 \end{pmatrix}, \quad (16)$$

and in position space

$$\begin{pmatrix} \chi'_0 \\ \chi'_1 \end{pmatrix} = \begin{pmatrix} \eta & 0 \\ 0 & \frac{1}{\eta} \end{pmatrix} \begin{pmatrix} \chi_0 \\ \chi_1 \end{pmatrix}. \quad (17)$$

Additionally, according to (12) and (15) one finds that transformations (16) and (17) must preserve the condition of zero invariant interval

$$(\pi_0)^2 - (\pi_1)^2 = (\pi'_0)^2 - (\pi'_1)^2 = 0, \quad (18)$$

and

$$(\chi_0)^2 - (\chi_1)^2 = (\chi'_0)^2 - (\chi'_1)^2 = 0. \quad (19)$$

The transformations (16) and (17), of course, are not unitary. On the other hand, since the Lorentz transformation (considered in position space) preserves the condition (19), it is clear, that it cannot relate two physically equivalent *photonic frames*. As noticed, in the case of $\eta \neq 1$ the time loses its kinematical meaning and becomes *frozen* only. Nevertheless, if one neglects the *vital* meaning of time, one finds that Lorentz transformation (which general form will be derived later) indeed relates the two *photonic frames* which are equivalent but in sense of *covariant equivalence*.

4.1 Description of *photon* state vector in *photonic frame*

The foregoing discussion shows that *photon* dispersion relation (10) is form invariant with respect to the *scaling transformation* (16). The same concern the relation (11) and transformation (17). Since the both *scaling transformations* act upon appropriate frame axes, they are the passive transformations. However, the *scaling transformation* may be considered also as the active one. The approach requires then that passive and active actions are to be equivalent. But this, in turn, gives rise to a question about the correct form of vector representing the *photon* state in *photonic frame*. Let us take a closer look at this issue.

The two-dimensional energy-momentum *photonic frame*, introduced above, gives us possibility to represent a physical state in form of two-component vector $\begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix}$, called further the *bimomentum*. The action of *active scaling* must then transform $\begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix} \rightarrow \begin{pmatrix} \Pi'_0 \\ \Pi'_1 \end{pmatrix}$ where

$$\begin{pmatrix} \Pi'_0 \\ \Pi'_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\eta} & 0 \\ 0 & \eta \end{pmatrix} \begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix}. \quad (20)$$

Now, let us assume that *photon* state is represented by *bimomentum* which components Π_0 and Π_1 are related by (10). Thus, one would expect that components of new *bimomentum* $\begin{pmatrix} \Pi'_0 \\ \Pi'_1 \end{pmatrix}$ still fulfill relation (10). However, since *bimomentum* $\begin{pmatrix} \Pi'_0 \\ \Pi'_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\eta}\Pi_0 \\ \eta\Pi_1 \end{pmatrix}$, one finds that *bimomentum* $\begin{pmatrix} \Pi'_0 \\ \Pi'_1 \end{pmatrix}$ cannot represent *photon* state in the *photonic frame* in which the bimomentum $\begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix}$ does. So, one needs to indicate another *bimomentum* form capable to describe the *photon* state correctly.

As noticed, the covariant description uses the frame which axes, originally given in different physical units (like energy and momentum), become “physically equivalent” after the comparison scale has been imposed. On the other

hand, the magnitudes of energy and momentum of *photon* state (just in covariant description) are assumed to be equal. This enables *photon* state vector to be put down in the form *bimomentum* which one component of two equals zero. Indeed, the scaling transformation (16) acting on state vectors $\begin{pmatrix} \Pi_0 \\ 0 \end{pmatrix}$ or $\begin{pmatrix} 0 \\ \Pi_1 \end{pmatrix}$, does not take them out of this *bimomentum* class. Thus, the *photonic frame* might be called also the frame which one-component *bimomenta* describe the *photon* states. The problem related to ambiguous interpretation of described this way *photon* states, is discussed next.

5 The *gauge* frame description

The analysis has been doing so far is $1 + 1$ dimensional. However, if one concentrates only on dynamical properties of single (scalar) particle, such $1 + 1$ dimensional analysis turns out to be the *gauge* analysis. Indeed, let us call the axis along which particle propagates, the *gauge axis*. So, if the momentum axis covers the *gauge axis*, one finds that our $1 + 1$ dimensional energy-momentum frame is to be considered the *photonic gauge frame* in $3 + 1$ dimensional space. Consequently, the two-component *bimomentum* $\begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix}$ turns out to be the *gauge* form of four-momentum.

The bimomenta that belong to four different quarters of *photonic gauge frame* correspond to four different kinds of quantum states. In particular the bimomenta of quarters *I* ($\Pi_0 > 0, \Pi_1 > 0$) and *II* ($\Pi_0 > 0, \Pi_1 < 0$) describe particle which energies are positive but momenta are oriented respectively toward the positive and negative direction of the *gauge axis*. Analogical situation concerns the quarters *III* ($\Pi_0 < 0, \Pi_1 < 0$) and *IV* ($\Pi_0 < 0, \Pi_1 > 0$) where particle energies now are negative.

Next, let us consider the *photonic gauge frame* and one-component *bimomenta* $\begin{pmatrix} \Pi_0 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ \Pi_1 \end{pmatrix}$ assumed to represent the *photon* states in this frame. Then, the *bimomentum* $\begin{pmatrix} \Pi_0 \\ 0 \end{pmatrix}$ must describe a *photon* which energy is positive if $\Pi_0 > 0$, or negative if $\Pi_0 < 0$, but the direction of momentum transfer in both cases is indefinite. Similarly, the *bimomentum* $\begin{pmatrix} 0 \\ \Pi_1 \end{pmatrix}$ must describe a *photon* which momentum (in given coordinate frame) is positive if $\Pi_1 > 0$ or negative if $\Pi_1 < 0$, but energy sign is indefinite now. Discussed in the following the unitary equivalent representation of *photon bimomenta* allows us to remove these ambiguities.

5.1 The *photonic* vs. *Minkowski gauge* frames

Let us consider the *photonic gauge frame* and a new frame which axes p_0 and p_1 are rotated around the origin of the initial *photonic frame* about 45° . Then, the relationship between the coordinates of both frames is given by orthogonal transformation

$$\begin{pmatrix} p_0 \\ p_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} \pi_0 \\ \pi_1 \end{pmatrix}. \quad (21)$$

The particular choice of rotation angle of 45° makes that in the new frame the coordinates of *photon* vectors are put on diagonals, or, in other words, on light-cone axes. For example, the *photon* state described in initial *photonic frame* by *bimomentum* $\begin{pmatrix} \Pi_0 \\ 0 \end{pmatrix}$, and thus having indefinite direction of momentum transfer, in the new frame takes the form

$$\begin{pmatrix} P_0 \\ P_0 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} \Pi_0 \\ 0 \end{pmatrix}, \quad (22)$$

so that $P_0 = \Pi_0/\sqrt{2}$ and momentum transfer now is well-defined. Thus, the new frame will be called the *Minkowski gauge frame*. It is also worthwhile to notice that *bimomentum* $\begin{pmatrix} 0 \\ -\Pi_0 \end{pmatrix}$ of *photonic frame*, in the *Minkowski gauge frame* takes the form

$$\begin{pmatrix} P_0 \\ -P_0 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} 0 \\ -\Pi_0 \end{pmatrix} \quad (23)$$

which describes the *photon* that propagates in opposite direction with comparison to photon (22).

Next, let us see how the *scaling transformation* of *photonic frame* acts on *Minkowski gauge frame* axes.

5.2 Scaling transformation of *Minkowski gauge frame*

Let us consider again the *scaling transformation* of *photonic frame* (16). If one considers the two *photonic frames* defined for two different *comparison scales* η_1 and η_2 , one finds that *scaling transformation* relating these two frames still has the same form (16), but now $\eta = \eta_1 \cdot \eta_2$. Thus, the form of transformation (16) is general. Since there is unitary equivalence of *photonic* and *Minkowski gauge* frames it is advisable to determine the transformation of *Minkowski frame* induced by the *scaling transformation* of *photonic frame*. For that purpose, let us consider the two *photonic gauge frames* given for two different *comparison scales* η_1 and η_2 , and related to them the two *Minkowski gauge frames*. The corresponding transformations that relate both kinds of frames provide the formulas (21) and

$$\begin{pmatrix} p'_0 \\ p'_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{-\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} \pi'_0 \\ \pi'_1 \end{pmatrix}. \quad (24)$$

Thus, according to (16), (21) and (24) one obtains

$$\begin{aligned} \begin{pmatrix} p'_0 \\ p'_1 \end{pmatrix} &= \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{-\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} \frac{1}{\eta} & 0 \\ 0 & \eta \end{pmatrix} \begin{pmatrix} \pi_1 \\ \pi_0 \end{pmatrix} \\ &= \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{-\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} \frac{1}{\eta} & 0 \\ 0 & \eta \end{pmatrix} \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} p_0 \\ p_1 \end{pmatrix}, \end{aligned} \quad (25)$$

which finally leads to the known expression

$$\begin{pmatrix} p'_0 \\ p'_1 \end{pmatrix} = \begin{pmatrix} \cosh\xi & \sinh\xi \\ \sinh\xi & \cosh\xi \end{pmatrix} \begin{pmatrix} p_0 \\ p_1 \end{pmatrix}, \quad (26)$$

where $\xi = \ln\eta$ and $\eta = \eta_1 \cdot \eta_2$. Eq. (26), of course, is the Lorentz transformation of 1 + 1 dimensional momentum *gauge frame*. One easily finds that Lorentz transformation (26) is equivalent to the *scaling transformation* of light-cone axes in *Minkowski gauge frame*, or alternatively, to the *scaling transformation* of axes of *photonic frame*. This shows again (cf. eqs. (18), (19)) that source of Lorentz covariance is the *freedom of choice of comparison scale*, which, as it comes from above, is embedded already at the level of quantum-mechanical description.

The issue of *photon* dispersion relation made visible that concept of *comparison scale* may be used to combine the postulates of Planck and de Broglie in Lorentz covariant way. The following section in a natural way extends above analysis into description of relativistic particle with mass.

6 Composite structure of massive states

Actually, there are two well-known examples of theoretical approaches where quantum objects are treated as extended ones. The first one provides the string theory [5]. The other, much more elementary, however much more closely related to usual quantum mechanics, provides the model of covariant harmonic oscillator [6],[7]. Nevertheless, these two quite different approaches share the same idea of particle mass introduction. Indeed, because of assumed particle internal space-time structure, in both cases particle mass does not appear as a description parameter (like in the case of know Dirac equation) but, one may briefly say, it is extracted from massless wave equation. Presented below simple quantum-mechanical analysis in some sense confirm these results and indicates that massive states, indeed, can be constructed with aid of the massless ones.

The transformation (21) representing the transition from the *photonic* to *Minkowski gauge frame* was introduced to describe the *photon* states in clear-cut way. This transformation, however, also enable us to identify a *two-photon* state represented by two-component *bimomentum* of *photonic frame* with a massive state represented by *bimomentum* of *Minkowski gauge frame*. Indeed, let us consider the *bimomentum*

$$\begin{pmatrix} \Pi_0 \\ \Pi_1 \end{pmatrix} = \begin{pmatrix} \frac{mc}{\sqrt{2}} \\ -\frac{mc}{\sqrt{2}} \end{pmatrix}, \quad (27)$$

assumed to describe a particle with mass m in *photonic gauge frame*. According to (21), the corresponding form of *bimomentum* (27) in *Minkowski gauge frame* is

$$\begin{pmatrix} p_0 \\ p_1 \end{pmatrix} = \begin{pmatrix} mc \\ 0 \end{pmatrix}, \quad (28)$$

which basically describes particle at rest. So, one finds that *bimomentum* of particle at rest in *Minkowski gauge frame* is unitary equivalent to the *bimomentum* of *two-photon* state, where each of the photons in Minkowski frame must propagate in opposite directions. Note, that such combination of *photon* states suggests that effectively introduced massive state is to be considered rather extended then point-like.

Next, let us consider the transformation (26) and note that it may be understood: (1) as the *passive* one, when both *bimomenta* $\begin{pmatrix} p_0 \\ p_1 \end{pmatrix}$ and $\begin{pmatrix} p'_0 \\ p'_1 \end{pmatrix}$ refer to the same physical state but they are described in two different reference frames (i.e. in frames based on different *comparison scales*), or (2) as the *active* one when both *bimomenta* are considered in the same *preferred frame* but refer to two different physical states. In the case (1) η is the *passive* parameter, whereas in the case (2) is the *active* one. So, in the latter case the η – *parametrization* does not concern the frame characteristics but describes dynamical features of the state. We write this down in the explicit form

$$\begin{pmatrix} p_0 \\ p_1 \end{pmatrix} = \begin{pmatrix} \gamma & \gamma\beta \\ \gamma\beta & \gamma \end{pmatrix} \begin{pmatrix} mc \\ 0 \end{pmatrix}, \quad (29)$$

where $\gamma = \cosh\xi$ and $\gamma \cdot \beta = \sinh\xi$. Formally, the transformation matrixes given in (26) and (29) are identical. However, the parameters γ and β (which kinematical meaning will be discussed latter) were introduced to emphasis that their values need to be refer to the frame set for $\eta = 1$.

Note, that massive states, which are assumed to be physically observed, now emerge as the effective ones in Minkowski frame description. Indeed, currently discussed mass-shell state was made up of two *photon* states. Furthermore, since the momentum transfer of these two *photon* states is opposite, the suspicion that massive particles should have some space-time extensions become justified. On the other hand, since the momentum transfer for each interaction process is assumed to be local, the picture of point-particle maintains its validity too. But this in turn means that classical picture of point particle and the quantum one of extended quantum object not necessarily have to be mutually exclusive.

7 Quantum-mechanical foundations of Minkowski space-time

In this section we extend $1 + 1$ dimensional *gauge* analysis onto entire $3 + 1$ dimensional space-time. We show that the origin of symmetry based on homogenous Lorentz group is still the same quantum-mechanical *freedom of choice of comparison scale*. Indeed, the scaling parameter η turns out to be the only relevant parameter of six-parameter Lorentz group, which makes sharp distinction between relativistic and classical approach. We show this explicitly by deriving the diagonal form of the Lorentz-boost transformation matrix. In first subsection we indicate that Minkowski space-time, first of all, is to be consider energy-momentum reciprocal space, what means that space-time description,

in general, provides only the *frozen time* meaning. The next two following subsections are devoted to issue of kinematical meaning of time in relativistic approach.

7.1 Diagonal form of Lorentz-boost transformation

The *scaling transformation* expressing the *freedom of choice of comparison scale* of $1 + 1$ dimensional *photonic frame* in momentum space was shown to have the form (16). Similarly it was shown that eq. (17) describes the space-time transformation equivalent to (16) but considered in reciprocal momentum space. Now, we generalize our analysis onto entire space, assuming that the *gauge-axis* of $1 + 1$ dimensional *photonic frame* is the x - *axis* of $3 + 1$ dimensional frame. In this frame the *scaling (gauge) transformation* (17) must take the form

$$\begin{pmatrix} \chi'_0 \\ \chi'_1 \\ \chi'_2 \\ \chi'_3 \end{pmatrix} = \begin{pmatrix} \eta & 0 & 0 & 0 \\ 0 & \frac{1}{\eta} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \chi_0 \\ \chi_1 \\ \chi_2 \\ \chi_3 \end{pmatrix}. \quad (30)$$

According to (21), one finds that appropriate transitions from the *photonic* to *Minkowski gauge* frame in the case of $3 + 1$ dimensional space-time must be given by orthogonal transformations

$$\begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \chi_0 \\ \chi_1 \\ \chi_2 \\ \chi_3 \end{pmatrix}, \quad (31)$$

and

$$\begin{pmatrix} x'_0 \\ x'_1 \\ x'_2 \\ x'_3 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \chi'_0 \\ \chi'_1 \\ \chi'_2 \\ \chi'_3 \end{pmatrix}. \quad (32)$$

Thus, combining of eqs. (30), (31) and (32) one finds that *scaling transformation* of *photonic gauge frame* corresponds to the Lorentz transformation of $3 + 1$ dimensional frame

$$\begin{pmatrix} x'_0 \\ x'_1 \\ x'_2 \\ x'_3 \end{pmatrix} = \begin{pmatrix} \cosh\xi & -\sinh\xi & 0 & 0 \\ -\sinh\xi & \cosh\xi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix}, \quad (33)$$

where $\xi = \ln\eta$. In matrix notation eq. (33) is

$$x' = A_0 x. \quad (34)$$

Next, let us determine the new form of transformation matrix A_0 in the case, where both (mutually parallel) Minkowski frames are additionally rotated

about their origins in the same way. This corresponds to the situation, where the *gauge-direction* does not match any of Minkowski frame space axes. Let then us rotate the initial frames, first (let say) in xy and next in yz plane, according to

$$R_{yz}R_{xy}x' = R_{yz}R_{xy}A_0R_{xy}^{-1}R_{yz}^{-1}R_{yz}R_{xy}x, \quad (35)$$

where

$$R_{xy} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\varphi & -\sin\varphi & 0 \\ 0 & \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad R_{yz} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\psi & -\sin\psi \\ 0 & 0 & \sin\psi & \cos\psi \end{pmatrix}, \quad (36)$$

so that, the angles φ and ψ describe the rotations around the z and x axes respectively. The explicit form of eq. (35) is given by

$$\begin{pmatrix} x'_0 \\ x'_1 \\ x'_2 \\ x'_3 \end{pmatrix} = \begin{pmatrix} \gamma & -\gamma\beta_1 & -\gamma\beta_2 & -\gamma\beta_3 \\ -\gamma\beta_1 & 1 + \frac{(\gamma-1)}{\beta^2}\beta_1^2 & \frac{(\gamma-1)}{\beta^2}\beta_1\beta_2 & \frac{(\gamma-1)}{\beta^2}\beta_1\beta_3 \\ -\gamma\beta_2 & \frac{(\gamma-1)}{\beta^2}\beta_1\beta_2 & 1 + \frac{(\gamma-1)}{\beta^2}\beta_2^2 & \frac{(\gamma-1)}{\beta^2}\beta_2\beta_3 \\ -\gamma\beta_3 & \frac{(\gamma-1)}{\beta^2}\beta_1\beta_3 & \frac{(\gamma-1)}{\beta^2}\beta_2\beta_3 & 1 + \frac{(\gamma-1)}{\beta^2}\beta_3^2 \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix}, \quad (37)$$

where x and x' are now the “rotated equivalents” of those of eq. (34) and $\beta_1/\beta = \cos\varphi$, $\beta_2/\beta = \sin\varphi \cdot \cos\psi$, $\beta_3/\beta = \sin\varphi \cdot \sin\psi$, and thus $\beta = (\beta_1, \beta_2, \beta_3)$. Eq. (37) written in short cut form is

$$x' = \mathbf{A} x. \quad (38)$$

To recollect, the matrix \mathbf{A} represents the *Lorentz-boost* transformation. Traditionally it is derived by means of boost generators of the Lorentz group and the Taylor expansion [8]. The way in which it was constructed now, allows us to express the matrix \mathbf{A} in the form

$$\mathbf{A} = \mathbf{R}\mathbf{U}\mathbf{\Lambda}_\eta\mathbf{U}^{-1}\mathbf{R}^{-1}, \quad (39)$$

where

$$\mathbf{\Lambda}_\eta = \begin{pmatrix} \eta & 0 & 0 & 0 \\ 0 & \frac{1}{\eta} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad \mathbf{U} = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \quad \mathbf{R} = R_{yz} \circ R_{xy}. \quad (40)$$

Since neither of the matrixes \mathbf{R} nor \mathbf{U} is singular, the diagonal form of the matrix \mathbf{A} is given by $\mathbf{\Lambda}_\eta$. This shows that three boost parameters β_1, β_2 and β_3 emerge as a result of η -factor “splitting” induced by the orientation of the *gauge direction* in three dimensional real-space. Additional consideration of Euclidean real-space rotations, of course, is of no importance from the point of view of current analysis.

Let us briefly summarize the above results. It has been shown that idea of *comparison scale* implanted on very quantum-mechanical ground in straightforward manner leads to the concept of homogenous Lorentz group. The peculiarity of Lorentz symmetry comes from the fact that it embraces the features of geometrical and dynamical description (but not just only geometrical, as it is commonly thought). The Lorentz transformation emerge then quite naturally as the passive transformation of space-time, where the space-time turns out to be the reciprocal energy-momentum space. Therefore at the level of Lorentz covariant notation the time might have only the *frozen* meaning. On the other hand the quantum basis of Lorentz symmetry appears in the obvious way.

7.2 Kinematical meaning of Lorentz formulas

The Lorentz transformation formulas, due to textbook interpretation, involves the velocity as purely relative quantity. Indeed, if two, so-called, inertial observers (placed in their own rest frames) are in relative motion at velocity w , each of them is expected to measure the same velocity w of his moving co-partner. This expectation, however, is based on pure classical assumption that both observers, indeed, are quite equivalent. However, this is not the case of quantum measurement where one of the observers is to be substituted for a quantum object. Furthermore, in contrary to classical measurement, as already noticed, one cannot neglect the influence of measuring apparatus on the final results. In other words, the quantum observation always is the *preferred frame* observation. Thus, in particular, within the framework quantum measurement, the notion of (particle) velocity cannot be considered relative. If quantum description involves the Lorentz symmetry (what has been clearly shown already) then the orthodox point of view at the kinematical meaning of Lorentz formulas needs a thorough refinement. We start to discuss this issue by considering another velocity aspect, namely, its relationship with particle energy and momentum.

According to (29) the elements of transformation matrix (26) may be expressed by means of parameters

$$\gamma = \cosh\xi \quad \text{and} \quad \gamma \cdot \beta = \sinh\xi. \quad (41)$$

On the other hand the textbook formulas:

$$\gamma = \frac{1}{\sqrt{1 - w^2/c^2}} \quad \text{and} \quad \beta = \frac{w}{c}, \quad (42)$$

tell us how to relate the parameters (41) with some velocity w , interpreted as the velocity of point-particle moving at the observer rest frame. According to (42) and (29) the particle energy and momentum expressed by means of velocity w are

$$E = \frac{mc^2}{\sqrt{1 - w^2/c^2}}, \quad p = \frac{mw}{\sqrt{1 - w^2/c^2}}. \quad (43)$$

In similar manner the Lorentz transformation (34) combined with expressions

(41) and (42) takes the well-known form

$$t' = \frac{t - (w/c^2) \cdot x}{\sqrt{1 - w^2/c^2}}, \quad x' = \frac{x - w \cdot t}{\sqrt{1 - w^2/c^2}}, \quad y' = y, \quad z' = z. \quad (44)$$

Since the velocity w is the kinematical parameter of observer rest frame, the same must concern the time t and distance x . However, the key issue is that due to the orthodox interpretation, t' and x' are also kinematical parameters but referring to the particle rest frame. The arguments given through the paper clearly indicate that currently such interpretation is not allowed. In particular, it is commonly thought that the time passing at the rest frames of observer and particle are different. The source of such misleading interpretation, let us emphasize once more, is a false conviction that the picture of particle moving at observer rest frame is physically equivalent to the one where the particle stay at rest but the observer moves. There is no equivalence between the rest frames of observer and particle. Furthermore, in fact, it is even hard to say what does the notion of particle rest frame mean. The particle is only a quantum object and cannot be identified with any physical observer. On the other hand, it does make sense to say that the observer, in his own rest frame, observes different quantum states of given quantum object. This is why the Lorentz transformation cannot preserve the *vital time* meaning, and thus the formulas (44) cannot relate two physically equivalent frames.

7.3 Quantum-mechanical explanation of time dilatation effect

Presumably, the most natural question arising now is how to explain the, so-called, time dilatation effect. Although satisfactory discussion of this issue requires a field theory approach, as well as, a new insight into Heisenberg uncertainty principles [9], a simply quantum-mechanical explanation can be given right now.

First, let us note that the parametrization of γ and β (42) is not unique. An alternative expressions can be found by introducing a new velocity v related to w according to

$$v = \frac{w}{\sqrt{1 - w^2/c^2}}. \quad (45)$$

This yields

$$\gamma = \sqrt{1 + v^2/c^2} \quad \text{and} \quad \gamma \cdot \beta = \frac{v}{c}. \quad (46)$$

As a result, the energy and momentum formulas (43) may be replaced by the new ones

$$E = mc^2 \sqrt{1 + v^2/c^2}, \quad p = mv. \quad (47)$$

One sees that momentum (47) has the classical form, whereas the energy is regular function of v in the whole range. Since the velocities which magnitudes are grater then c are, in general, not observed, the physical interpretation of

expressions (47) is rather troublesome. The most straightforward way to overcome this difficulty is to treat both velocities w and v on equal physical footing. Indeed, let us assume again that particle seen as a quantum object may exist under the cover of two forms, seemingly quite different, but in fact, complement one another.

The first form is assumed to have point-particle features, whilst the other the features of extended quantum object. Let us then assume that in the first, classical-like case, the moving particle is identified with point-like object of mass m , which covers the distance Δl at velocity v in time period Δt_v .

Next, to ascribe to the particle of the second possible form of existence (which does not have classical counterpart), let us make a striking assumption that this extended quantum form correspond to the state which is temporarily localized in observer rest frame, which longitudinal extension is just Δl and which life-time is Δt_w where

$$\Delta l = w\Delta t_w = v\Delta t_v. \quad (48)$$

According to (45) one finds that relation between the time intervals Δt_w and Δt_v is

$$\Delta t_w = \frac{\Delta t_v}{\sqrt{1 - w^2/c^2}}. \quad (49)$$

Thus, the assumption of quantum (localized and extended) and classical (point-like and not localized) particle nature provide us simply and plausible interpretation of formulas (48) and (49). In particular, one finds that formula (49) relates the life-times of moving point-particle and corresponding quantum state. If Δt_v is the life time of unstable particle, then simple quantum-mechanical approach may explain why “relativistic particle” produced at some point x_A can be found at point x_B distant from x_A much more than the light pulse can travel at the time period Δt_v . On the other hand, if the life time of assumed temporarily localized state is also the time needed for the measurement to establish the point-particle position, one finds that causality is always preserved.

The complete quantum description of extended quantum state (now introduced only in classical-like manner), of course, should be characterized through the covariant probability distribution, localized in some space-time region. Currently, let us stress only that examples of such distributions provide us just mentioned solutions of covariant harmonic oscillator. To maintain the paper simplicity, however, it is advisable to separate this issue from the discussion right now.

Finally, let us note that Lorentz transformation formulas (44) can be written down in alternative form involving velocity v instead of w , namely

$$t' = t\sqrt{1 + v^2/c^2} - \frac{v}{c^2}x, \quad x' = x\sqrt{1 + v^2/c^2} - vt, \quad y' = y, \quad z' = z. \quad (50)$$

The formulas (44) and (50) express the same *passive* transformation (33), which corresponds to the same change of comparison η – *scale*. Thus, the kinematical

meaning of t' and x' in formulas (44) and (50) is lost. The case of $\eta \approx 1$, corresponding to small velocity values, reduces the both kinds of Lorentz formulas to the Galilean form, and thus provides us the “true” classical limit.

8 Concluding remarks

Discovery and research of classical electromagnetic field, undoubtedly, occupy central position in development of physics. Although experimental basis of Maxwell equations is thought to be the classical one, in fact, the very object of Maxwell equations, as well as, their algebraic structure go much beyond the framework of pure Newton world picture. One of the main reason for that is, of course, that Newton theory deals with the concept of material point, which, in wave description, does not have a simple counterpart. The most closely related to this notion is the one of quasiparticle, but it appears already at the level of second quantization. Furthermore, the mechanics of material point(s) and waves, in both cases called the classical, start with descriptions based on different symmetry groups. Thus, an arising question is whether the Lorentz symmetry might be called classical (i.e. not quantum) at all. Note that simple physical observations, such as the blackbody radiation or the photoelectric effect, clearly reveal the quantum nature of electromagnetic field and confirm the validity of *photon dispersion relation* (10). However, as it was explained, from the quantum-mechanical point of view, such dispersion relation can be set only with accuracy to the *freedom of choice of comparison scale*. Thus, the practical measurements have to use the physical *photon system* as the preferred or standard one in order to plot the values of energies and momenta of other quasiparticle excitations on absolute, i.e. *preferred frame*, energy and momentum scale. Here, one needs to emphasize that such distinguished role of *photon system* has been already noticed in [10]. Nevertheless, the Lorentz symmetry always is thought to manifest the classical, i.e. purely geometrical properties of space-time.

Indeed, the notion of space-time takes its origin from the classical (i.e. Newton-like) analysis of electromagnetic field. The six-parameter, homogenous Lorentz group, or in more general case (when space-time translations are included), the ten-parameter Poincaré group, determine the algebraic properties of space-time. According to orthodox view the physical background of this symmetry is Einstein idea of relativity. It is well-known that such point of view is the source of old twin-paradox. Although most of the physicist get used to it and see nothing wrong with that, is worthwhile to notice that this paradox still comes back to life, however, under the new cover [10], [11]. Then, one may ask what forces us to believe something which is to be challenged. A few sentences taken from the book of Kim and Noz [7] might be the answer to this question.

“Developing a new physical theory usually requires a new set of mathematical formulas. There are in general two different approaches to this problem. According to Eddington we have to understand all the physical principles before writing down the first mathematical formula. According to Dirac, however, it

is more profitable to construct plausible mathematical devices which can describe quantitatively the real world, and then add physical interpretation to the mathematical formalism. Both special relativity and quantum mechanics were developed in Dirac's way, and most of the new physical models these days are developed in this way".

This paper, in the most elementary way, indicates that quantum mechanics itself provides plausible and reasonable translation of special relativity language. As noticed by Kim: "If not possible, it is very difficult to formulate Lorentz boosts for rigid bodies. On the other hand, it seems to be feasible to boost waves" [12]. The view that Lorentz symmetry reflects the relativity of time and length measure is a misunderstanding. To justify the introduction of relativistic description the support of orthodox relativity principle is not needed. Note that derivation of Lorentz transformation (26) or (33), in fact, encompasses only the quantum-mechanical postulates of Planck and de Broglie and the *idea of comparison scale*. Thus, one easily finds that Lorentz space-time transformation is simply the passive transformation of reciprocal four-momentum space. The time that undergoes relativistic transformations rules is only the *frozen time*, whereas the kinematical (*vital*) time meaning can be ascribed only to the *preferred frame*, which is the rest frame of the observer.

In summary, the main conclusion of this paper is that Lorentz symmetry is the symmetry of quantum description resulting from the *freedom of choice of comparison scale*. The Lorentz symmetry then is the symmetry of *preferred frame* description.

References

- [1] A. Einstein, Ann. Physik **17**, 891 (1905).
- [2] E. Schrödinger, Ann. Phys. **81**, 109 (1926); O. Klein, Z. Phys. **37**, 895 (1926); V. Fock, Z. Phys. **38**, 242 (1926); *ibid.* **39**, 226 (1926); W. Gordon, Z. Phys. **40**, 117 (1926).
- [3] see the comments of P. M. A. Dirac: Nature **189**, 355 (1961), Scientific American **208**, 45 (1963), *The Development of Quantum Theory*, Gordon and Breach, New York, 1971.
- [4] J. S. Bell, Phys. Rep. **137**, 7 (1986).
- [5] For instance see M. B. Green, J. H. Schwarz and E. Witten, *Superstring Theory*, vols. 1 and 2, Cambridge U. P., Cambridge, UK (1987); J. Polchinski, *String Theory*, vols. 1 and 2, Cambridge U. P., Cambridge, UK (1998).
- [6] Y. S. Kim and M. E. Noz, Phys. Rev. D **8**, 3521 (1973); Y. S. Kim and M. E. Noz, Phys. Rev. D **15**, 335 (1977).
- [7] Y. S. Kim and M. E. Noz, *Theory and Applications of the Poincaré Group*, (Reidel, Dordrecht, 1986).

- [8] For instance see J. D. Jackson, “Classical Electrodynamics”, John Wiley & Sons, Inc. (1975).
- [9] P. Korbel, in preparation.
- [10] G. Amelino-Camelia, Phys. Lett. B **510**, 255 (2001), hep-th/0012238, Int. J. Mod. Phys. D **11**, 35 (2002), gr-qc/0012051.
- [11] J. Magueijo and L. Smolin, Phys. Rev. Lett. **88**, 190403 (2002); G. Amelino-Camelia, Nature **418**, 34 (2002); J. Magueijo, Rept. Prog. Phys. **66**, 2025 (2003), astro-ph/0305457; J. Magueijo and L. Smolin, hep-th/0401087.
- [12] Y. S. Kim, physics/040327.